U.S. Department of the Interior

National Park Service

Geomorphologic Monitoring Protocol for the Northeast Coastal and Barrier Network

Part I –Shoreline Position

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I. Introduction

As part of the congressionally mandated Natural Resource Challenge, the National Park Service has created thirty-two monitoring networks to ensure the systematic collection and use of scientific data in managing the nations parks (NCBN 2003). This document represents the first in a series of protocols for long-term geomorphological monitoring in the eight parks that comprise the National Park Service Northeast Coastal and Barrier Network (NCBN)[1] (Figure 1).

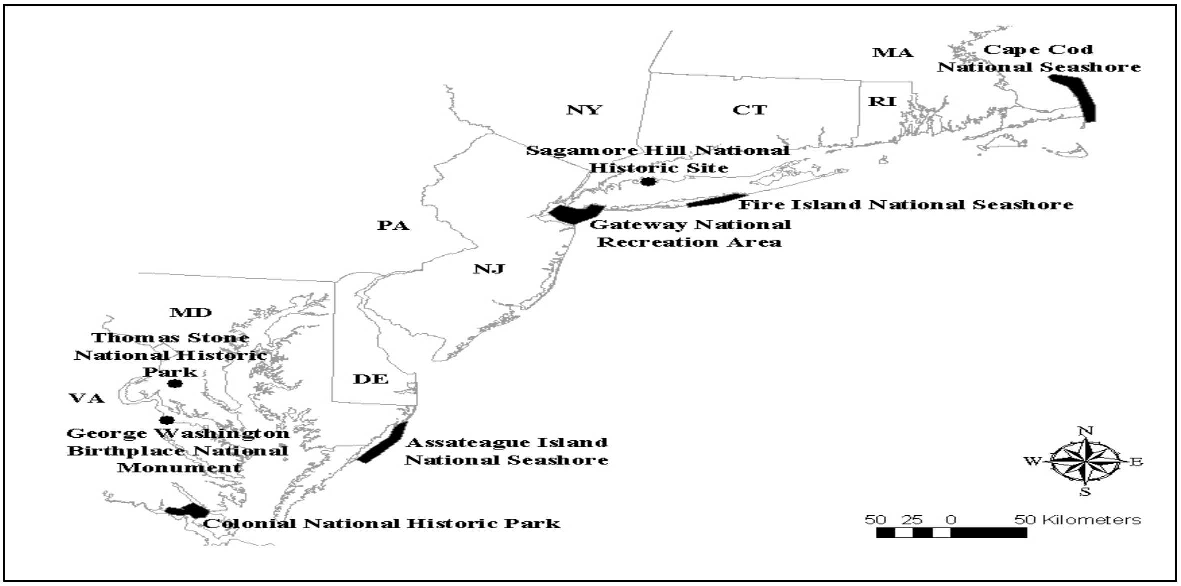

Figure 1 – Parks of the Northeast Coastal and Barrier Network

The NCBN coastal geomorphology program and its protocols are driven by three underlying principles:

1. The protocols have a scientific foundation. They have been developed with the collaboration of the scientific community and are based on well-established scientific principles of coastal characterization and response. Because coastal geomorphology is a complex subject, valid interpretation of the data will require the active involvement of knowledgeable coastal scientists.
2. The data collected will address significant park management issues. Park managers and natural resource staff were active participants in the planning and scoping process. The objectives identified in this protocol reflect a consensus of issues considered relevant at the park level. All aspects of the protocol focus on recording and assembling the geomorphologic dataset so that better informed management decisions can be made.
3. The data needs, collection methods, and analysis and reporting techniques are feasible to implement at the Network level. The scientific and management value of the monitoring data, along with the practicality of implementation, were major factors in determining which indicator variables were selected for monitoring.

[1] The eight parks in the Northeast Coastal and Barrier Network are Assateague Island, Cape Cod, and Fire Island National Seashores, Colonial National Historical Park, Gateway National Recreation Area, George Washington Birthplace National Historical Monument, and Sagamore Hill and Thomas Stone National Historic Sites.

These objectives will be met by monitoring a number of physical indicators in ocean, estuarine, and coastal riverine systems. The indicators occur in both the terrestrial and marine environments and together constitute the overall coastal geomorphologic envelope of concern. A systematic assembling and a rigorous analysis of a multi-feature dataset are essential to understanding the complex processes and associated responses that operate at the park level. However, practical considerations that balance data value and feasibility against available resources require a prioritization in the development of the many features designated for monitoring.

Based on these weighting factors, change in ocean shoreline position was selected as the first of the geomorphologic monitoring protocols for development. Shoreline position is a feature that contains high data value, high feasibility, its collection is readily implementable at the park and network level, and the data assembled can be quickly and effectively incorporated into park management operations.

The protocol is accompanied by a companion set of highly detailed standard operating procedures (SOP). Note: the SOP's are currently under development. They are intended to ensure the consistency and repeatability essential to any long-term monitoring program. These SOPs will be modified and revised as technology improves and methods for monitoring coastal geomorphologic change are refined.

II. Background and Objectives

<u>The Conceptual Framework of Coastal Geomorphologic Change</u>

Coastal ecosystems are dynamic environments driven by numerous natural and anthropogenic agents of change (Figure 1). Sea-level rise, sediment supply, and wave climate are the primary natural disturbances that drive geomorphologic change. These variables influence coastal geomorphological response at temporal scales that include individual events (storms), cyclic variations (seasonal), and multi-year (long-term) trends. The effects of the long-term trend of sea-level rise cause an inland displacement of the shoreline. When coupled with erosion produced by a prevailing sediment deficit, the result is an increased shoreline displacement (National Research Council 1987; Warrick 1993). Whereas, sea-level and sediment supply are the primary general factors, wave climate is the principle agent that steers the local sediment transport and consequently controls the site-specific shoreline configuration (Tranhaile 1997).

Local conditions such as the underlying geologic framework, offshore topography, and sediment sources and sinks interact with these primary agents of change to influence the rates and direction of coastal system response (Honeycutt and Krantz 2003). In addition to global, regional, and local natural causes, coastal erosion is often accelerated by human perturbations such as dredging, stabilizing structures, and beach and dune disturbance. These human influences can cause changes to waves, currents, and availability and mobility of sediment which in turn cause significant morphological and ecosystem response (Nordstrom 2000)

Coastal ecosystem response may consist of alterations to resource patterns and dynamics, and may eventually lead to the loss of fixed natural resources (Roman and Nordstrom 1988). These responses often elicit secondary changes in ecosystem structure or function. Structural changes in species composition or competitive interactions generally reflect landscape-level alterations in the quantity and quality of specific habitats. Similarly, functional changes in productivity or nutrient cycling may occur as a product of storm events and the associated reduction in habitat complexity. More subtle physical changes also include alterations in geo-chemical and hydrologic conditions, such as groundwater quality and quantity. The magnitude and scope of the resultant coastal ecosystem response is complex, highly variable, and can often be cumulative. At the extreme, this includes the alteration of habitats and of core ecosystem processes, such as when erosion from severe storms creates new aquatic habitat at the expense of terrestrial habitat.

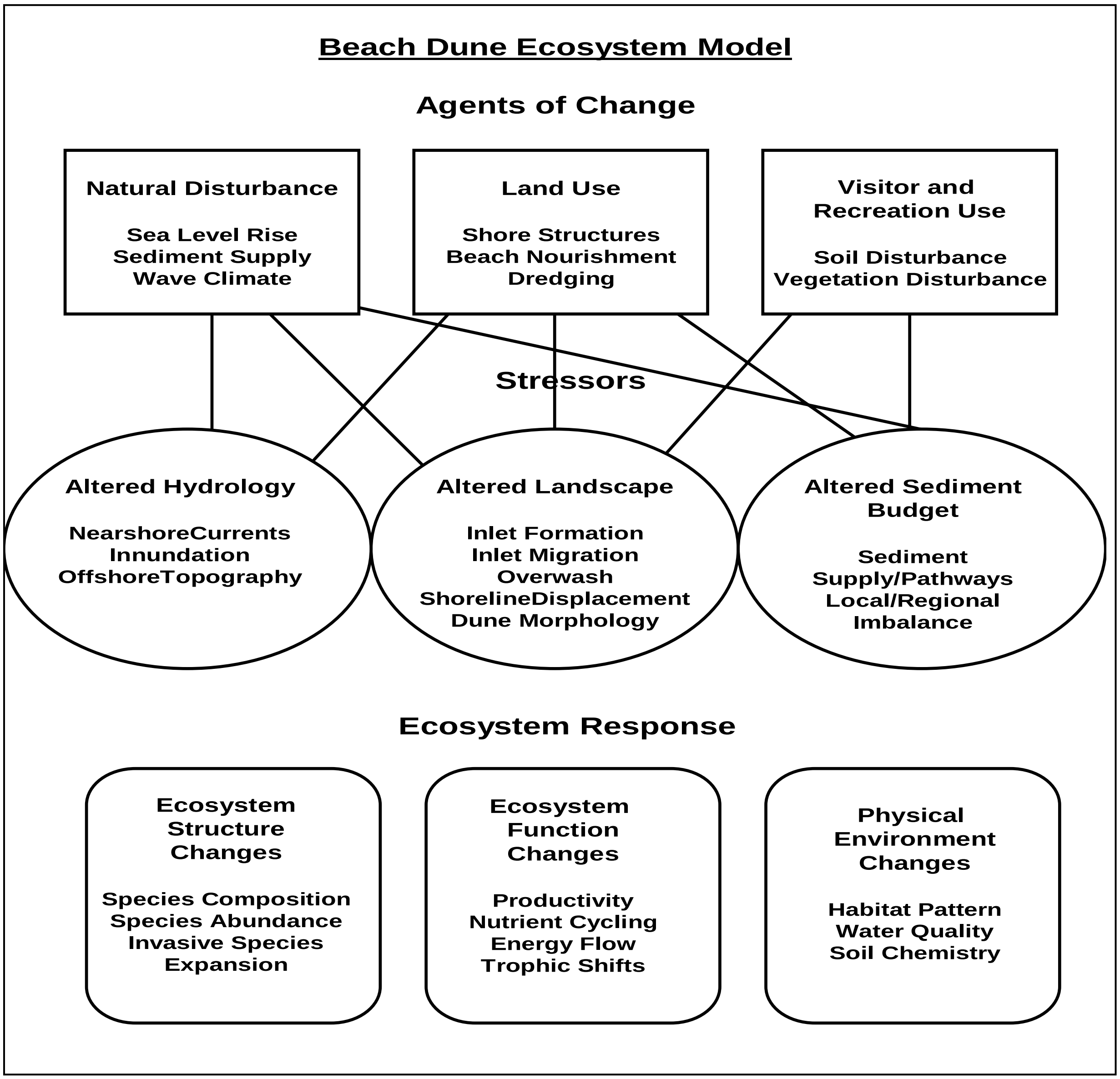

Figure 2 – Ocean Beach and Dune Conceptual Model

Vital Sign Identification

Geomorphologic change not only affects park ecosystems, it also poses a significant threat to cultural resources, recreational features and facilities, and infrastructure. In order to address the full range of scientific and management concerns, multiple scoping workshops were convened to identify issues of general importance and to make specific recommendations for monitoring. Throughout the scoping process, the lack of adequate data to track and respond to geomorphologic change was consistently identified as a high priority management issue. Demonstrating the complexity of the coastal geomorphologic process, twenty-nine potential monitoring variables of geomorphologic change were identified by the workshops (NCBN 2003). Following the workshop, the number was reduced by combining similar indicators and eliminating redundant items. The remaining fourteen indicators were evaluated and ranked for data value and feasibility of implementation at the network level (Table 1).

Vital Sign	Measurement	Monitoring Methods	Feasibility	Data Value
Shoreline Position	Land-Water Contact	2D and 3D GPS, Aerial Photography, LIDAR	high	High
Topography	Dune, cliff, bluff features	LIDAR Aerial Photography, 3D GPS	high	high
Topography	Edge of vegetation	LIDAR, 2DGPS, Aerial Photography	high	high
Topography	Landcover	LIDAR, 3D RTK GPS, 3D Survey	high	High
Topography	Overwash fans/flood plains	LIDAR 2D GPS Survey, Aerial Photography	medium	high
Manipulations	Locations of structures and disturbances	Aerial Photography, 2D and 3D GPS, Ground Survey	medium	high
Land Use	Shore type	Aerial Photography 2D and 3D GPS, Ground Survey	medium	medium
Sediment	Sediment quantity Sediment size	Terrestrial and Marine Sediment Samples	medium	medium
Geology	Geologic framework	Acoustic Survey, Seismic Survey, Core Samples	low	high
Bathymetry	Depths	Acoustic Survey, Bathymetric LIDAR, Sled survey	low	medium
Bathymetry	Migrating shoals & bodies	Acoustic Survey, Bathymetric LIDAR	low	high
Hydrology	Tide range	Local & Regional Tide Gauge	high	high
Hydrology	Relative sea level position	Water Level Gauge	high	high
Hydrology	Wave and current characteristics	Local GaugeRegional Gauge	low	high

Table 1 – Potential Vital Signs

Monitoring Coastal Shoreline Change

Detailed knowledge of the hydrodynamic forcing of sediment mobilization, transport, deposition, and measurements of morphologic change and ecosystem response at the park level is key to understanding the coastal geomorphology of NCBN parks (Allen 2000). Whereas a number of indicators of coastal dynamics are difficult to measure there are several indicators and expressions of the overall coastal process-response continuum such as shoreline position that can be measured effectively and can be used to address park management issues. From a scientific perspective, shoreline position represents the balance of wave and current processes acting upon sediment supply. From the park's point of view, knowledge of shoreline position and its change offer a scientific basis for informed resource management. Additionally, there is a knowledge base of historical shoreline positions that supports long-term comparison. Furthermore, measuring shoreline position is readily accomplished using existing technology and methods. Because it provides high information content and is easily implemented at the Network level, shoreline position was selected for protocol development.

Shoreline change exhibits a high degree of spatial and temporal variability (List 1993). Understanding the long-term variability is key to recognition of geomorphological and ecological issues in coastal parks (Allen 2000). Therefore, monitoring of shoreline characteristics creates the dataset needed to establish rates of change and to determine multi-scale variability. The assemblage of reliable and consistent data enables robust statistical analysis, yielding a better understanding of episodes, cycles, and trends. The result is a rigorous monitoring program that leads to improved knowledge of the results of coastal processes and consequently to better informed management.

Historical Development of Methods used for Monitoring Shoreline Position

Coastal mapping and the measuring of coastal features have utilized an evolving suite of data collection methods. Early techniques involved the National Ocean Service (NOS) and the National Geodetic Survey (NGS) and their in situ surveys of the coast. This method was extremely labor intensive and the long time periods required to complete a survey proved to be problematic in capturing anything resembling an instantaneous shoreline position. However, these early efforts did result in systematically collected datasets that were suitable for general delineation and comparison of coastal features, and they established general baselines in many coastal areas (Graham 2003).

The development of aerial photography in the early twentieth century created the opportunity for rapid data collection and the extraction of multiple features from the images (Moore 2000). Comparison studies between ground surveys and aerial photography showed a general level of compatibility between the data (Krauss 1997). The ability to capture large geographic areas of the coast continues with space based satellites. Satellite technology is becoming a viable option for many coastal data acquisition purposes. Currently there are multiple studies within the NCBN to assess the utility of satellite imagery for coastal mapping.

The last twenty years have seen a revolution in mapping sciences in general and coastal mapping sciences in particular. The development of Geographic Information Systems (GIS) allows the simultaneous display, manipulation, and analysis of multiple datasets. In the 1980s and 1990s, GIS technology was augmented by the addition of satellite based Global Positioning Systems (GPS), creating the opportunity for more efficient, frequent, and precise measures of geomorphologic features. Together these technologies greatly increased the capacity for updating, analyzing, and reporting changes in coastal conditions.

The revolution in coastal mapping continued into the 1990s when LIDAR (light distancing and ranging) technology was applied to the coastal zone (Krabill 2000). The airborne laser mapping system could deliver high-resolution measurements of the entire non-vegetated beach and dune system and use the three dimensional data to extract a variety of coastal features including shoreline position. LIDAR technology has evolved rapidly and systems now exist that can penetrate sparse to moderate vegetation (Wright and Brock 2002) and some shallow waters to provide detailed topographic and bathymetric data over large segments of coastal systems.

NPS geomorphologic monitoring has generally mirrored the developments in the coastal sciences (Allen and LaBash 1997) In some cases, the NPS has played a major role in the development of modern, technology-based data acquisition efforts (Brock 2001). Network parks were early users of GPS shoreline surveys and a NASA research experiment in the mid-1990s was one of the earliest cases of LIDAR technology applied to beach mapping.

Currently, there are a variety of independent data collection activities underway in individual NCBN parks. At present, none of these efforts meets the rigorous data collection and data management standards established by the service-wide inventory and monitoring program. However, many of the concepts, methods, and techniques used in individual park programs are applicable to network-wide long-term monitoring. By providing a consistent and systematic framework for collection, analysis, and reporting, the NCBN will take this collective knowledge and experience from existing park programs and build a long-term, network monitoring program.

Measurable Objectives

The NCBN Geomorphologic Monitoring Program incorporates a range of coastal variables. The measurable objective of this specific protocol is the identification of the seasonal, annual, and long-term trends and variability of shoreline position. Meeting this objective addresses the following:

- **Question 1:** ***Is there a net displacement of the shoreline?***
- **Question 2:** ***What are the seasonal dimensions of the displacement?***
- **Question 3:** ***What are the storm related dimensions of the displacement?***
- **Question 4:** ***Does the net displacement vary alongshore?***
- **Question 5:** ***Is there a spatial or temporal trend in the shoreline displacement?***

Accomplishing the objective of this protocol – identifying the geotemporal variation of shoreline change – requires the following steps: 1) standardization of the survey methodology, 2) design and construction of the database and, 3) the analysis and reporting of the assembled data.

III. Sampling Design

Selecting the Shoreline Feature and Measurement.

The shoreline represents the intersection between water and land surfaces. The location of the intercept on the beach profile (Figure 2) varies due to the effects of tides, waves, and atmospheric conditions. Shorelines may be delineated based on a datum intercept, or identification of some morphological feature, or some visual characteristic. Multiple conventions and terms are used to describe the various positions of the intercept. Datum shorelines such as Mean High Water (MHW) are quantitative and use a calculated identification of an exact elevation to extract the intercept. (Parker 2003; Pajak and Leatherman 2002). On the other hand, morphologic features such as berm crest or cliff base, or visual features such as the high water mark or water's edge are qualitative and based on a visual interpretation. Any of these may be used to represent a shoreline position under specific circumstances.

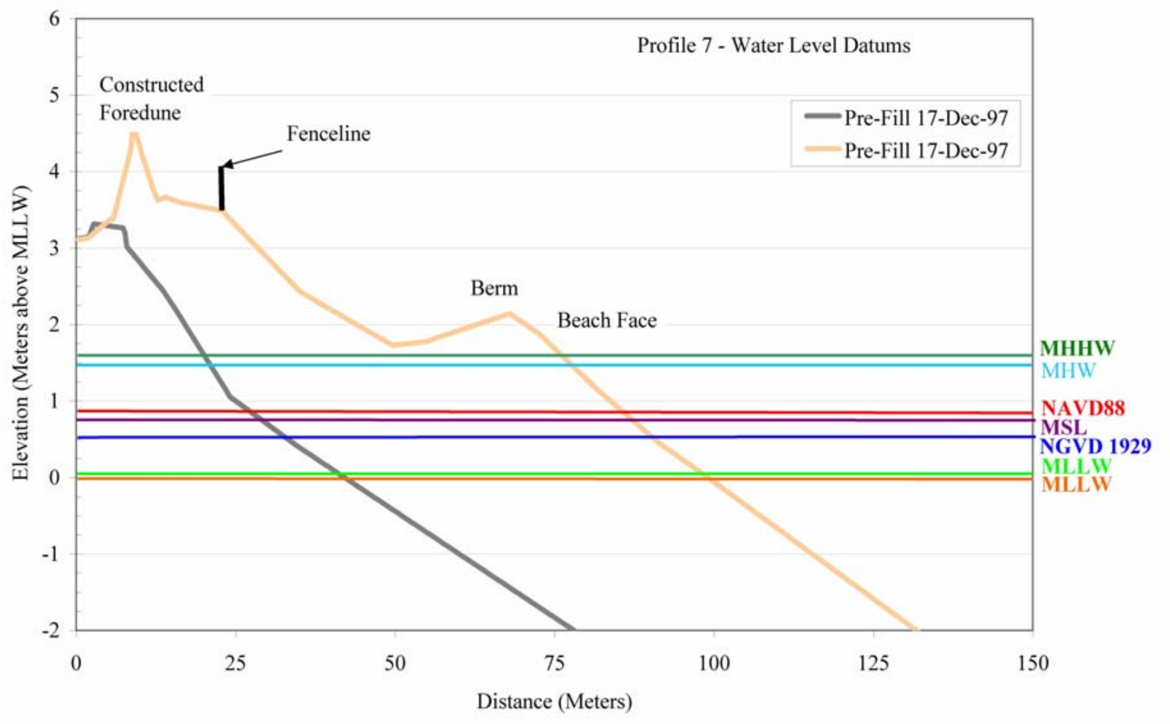

Figure x. Water level datums.

Figure 3 – Water Level Datums and Shorelines

Datum-based derivations are precise measures of shoreline position. However, Network-wide data collection necessary to extract this feature at the geotemporal scale required to identify seasonal and episodic variability is currently impractical because of financial resource limitations, lack of suitable equipment, and the absence of a tested methodology for regular and broad geographic data collection On the other hand, qualitative shorelines, derived through identification of a morphologic or visible cue, are less precise, but their derivation is feasible for use in a long-term, network-wide monitoring program (Pajak and Leatherman 2002). Among the qualitative features described above, the high tide swash line is consistently available, readily identified, and easily collected; and thus it is selected as the indicator of shoreline position in the data matrix (Figure 3). In the context of the NPS Network based monitoring program, a systematically planned and executed survey utilizing the high-tide swash line as shoreline position is well suited to the needs, resources, and capabilities of the program.

Due to its spatial variability, the determination of trends of changes in shoreline position requires both high resolution and high frequency data (Allen 1995). GPS-instrumented surveys of the high tide swash line balance the desire to limit spatial variability in the measurement with the need to maximize the spatial and temporal frequency of the data. Despite the qualitative nature of the approach, properly planned and executed GPS surveys can provide data sufficient to monitor the long-term trends and variability in shoreline position. Because timing of the survey can be adjusted for local tides and weather conditions, GPS surveys are both comparable and preferable to aerial photography, a traditionally-accepted method for shoreline mapping. Therefore, GPS surveys conducted at the local level will increase both the accuracy and efficiency of the measurement.

Although it has been determined that a GPS survey of the high tide swash line will be used to determine the shoreline position, the issue of the specific timing of the survey within the tidal cycle has yet to be resolved by the network. Field tests will be conducted over the next year by the NCBN geomorphology program staff and cooperators at various tidal stages to determine the variability of the high tide swash line. These tests will determine the timing of the survey within the tidal cycle to minimize its influence on variability. It is likely that the selection of the neap high tide swash line will minimize the spatial variability of the measurement.

Geographical Extent of the Surveys

In order to determine alongshore variability, the survey will encompass the entire length of the ocean beach at each of the network’s ocean parks (ASIS, CACO, FIIS, GATE). This will also include inlet shorelines from the ocean to their transition to bay process. A park specific description and map/diagram of the survey area is included in SOP #3 – Site Location and Geographical Extent.

Survey Frequency and Timing

Weather induced changes in wave climate produce a distinct seasonal response in the shoreline position (List and Farris 1999). These features typically reach their peak expression around the end of the winter and summer seasons. In order to track this seasonal variation, shoreline surveys will be conducted on a twice per year basis and timed to capture the general occurrence of the maximum seasonal (winter/summer) state. In general, the winter shoreline position will be collected in mid-to-late April and the summer shoreline position in early-to-mid October. Attention should be given to local weather conditions so as not to perform the seasonal survey in too close a proximity (< 1 week) to storm events or other abnormal weather conditions.

The shoreline survey should also be conducted when minimum satellite availability and satellite geometry specifications are met. Five satellites with a maximum position dilution of precision (PDOP) are the minimum recommended specifications for the survey. . In addition there may be park specific issues such as the presence of species of concern or public activities that constrain the conducting of the shoreline survey. Park management should always be consulted in advance when planning the survey. Details for timing and mission planning are provided in SOP #4 – Survey Timing and Mission Planning

As stated above, storm influenced beaches should be avoided when conducting the seasonal shoreline survey (Morton and Sallenger 2003). However, storm response shorelines provide important measures of short-term variation and can be of great value to both park managers and coastal scientists. Pre-and-post-storm shoreline positions should be collected whenever possible. Because numerous storms of varying intensity and duration are expected to affect a given park in a typical year, the decision of when to conduct these additional surveys is problematic. At this time, there is no quantifiable measure or formula to calculate what constitutes a qualifying storm event. Local observation and judgment must be exercised in making the determination whether or not to conduct the survey.

IV. Field Methods

Field Season Preparations and Mission Planning

Prior to the survey window, the entire protocol should be reviewed by the NCBN geomorphologic monitoring project manager, the designated field observer at each park, and any park or network staff or cooperators who will collect, process, or otherwise handle the shoreline data. Immediately following the protocol review, Internet URLs should be checked and mission planning for tides and satellite availability and satellite geometry should be initiated. Field equipment should be checked. Two of the determining factors for the timing of the survey are tide and satellite availability. Both tide and satellite availability should be analyzed and a list of potential survey dates and times established and prioritized. As the survey window approaches, extended weather forecasts should be obtained and analyzed so that storm conditions can be avoided. It is strongly recommended that a trial survey be conducted to familiarize the surveyor with the visual expression of the high tide swash line. A limited pre-survey test run may be sufficient. For additional detail refer to SOP#4 – Survey Timing and GPS Mission Planning.

Conducting the GPS Shoreline Survey

Surveys along the ocean shoreline are accomplished by driving a four-wheel all terrain vehicle (ATV) or four wheel drive truck at a relatively constant speed (between 5 and 10 mph) along the high tide swash line. For the purposes of this monitoring program, the actual ocean 'shoreline' is represented as the position of the most recent high tide swash, evidenced by the previous high tide wrack line or the most recent wet/dry sand line. The GPS receiver is configured to record positions at a very short interval (typically one position every 2 seconds or roughly every 10 meters) for the best representation of the shoreline position. The antenna should be positioned to be over the swash line. That is, the ATV should be driven so that the position of the antenna is located over the swash line and it is that position that is being recorded. At least one survey monument or some other marker with known coordinates should be embedded in the survey for general accuracy assessment. Details for conducting the GPS shoreline survey are included in SOP #7 – Conducting the GPS Survey.

Post-survey Data Download and Initial QA/QC

Immediately upon completion of the survey and return to the office, the GPS data file will be downloaded from the receiver to a computer hard-drive and a backup copy on compact disc (CD), digital video disc (DVD), or similar media should be created. The data should be retained on the data logger until quality checks can be made. The downloaded data should be visually checked for general spatial integrity and the file attributes reviewed for logical consistency. The GPS survey information should be entered in the appropriate GPS/Shoreline database and any abbreviated or summary metadata forms completed.

V. **Data Management (Reserved)**

Overview of Database Design

Data Entry, Verification and Editing

Metadata Procedures

Data Archival Procedures

VI. Data Analysis and Reporting (Reserved)

Recommendations for Routine Data Summaries and Change Analyses

Recommended Report Format - Examples of Summary Tables and Figures

Recommended Methods for Long-term Trend Analysis

VII. Personnel Requirements and Training

Roles and Responsibilities

The NCBN is responsible for the development and implementation of the protocol and has assigned a network staff-person as project manager. The project manager is responsible for coordinating protocol development as well as an implementation plan and schedule that is suited to the needs of the individual network parks. The project manager will work closely with network parks and their designated cooperators to develop and implement this protocol. The Northeast Coastal and Barrier Network Coordinator supervises the project manager.

The shoreline position protocol is designed to utilize local park staff in all phases of its execution. It is best for use by local park staff and their cooperators who have a basic understanding and working knowledge of the park and its resources. The protocol identifies sampling dates within a defined calendar range but also stipulates that data collection should take place during non-storm weather and neap tide conditions. Identification of suitable conditions and rapid deployment when they occur are much more effectively carried out by locally based field staff. Moreover, local staff are much better situated to perform periodic observations of the beach; because of their familiarity with its appearance. Their participation will thus greatly enhance accurate and consistent identification of the shoreline feature. The use of local staff also limits or prevents the problem of schedule overlap; where network staff and cooperators might be expected to work in multiple parks at or around the same time frame. Whereas the network parks are situated geographically so that sequential data collection might be possible, the vagaries of weather could easily create conditions that disrupt a tightly constructed schedule.

The use of local survey staff also allows rapid deployment of the survey team in the event of approaching storm events. It is possible that the approach and influence of a major mid-Atlantic hurricane or nor'easter could have a major impact at multiple network parks and warrant multiple and simultaneous pre- and post-storm surveys. Timely response by the network to this type of event would be unlikely. Trained and equipped local park staff would be much better situated to address this type of emergency or other episodic event.

Inconsistencies inherent to qualitative (visual) identification of the shoreline are reduced when the number of observers is limited. Whereas the targeted shoreline feature is not so ephemeral that it cannot be measured by different observers, it is logical to assume that no two observers will see or drive exactly the same shoreline. Spatial variability due to observer interpretation must be recognized and acknowledged. However, because the objective of the protocol is the establishment of long-term trends, it is likely that the minor inconsistencies introduced through the use of multiple observers will not seriously affect the value of the data. Nonetheless, consistent feature identification and measurement is important and assignment of data collection to a single or small number of observers is highly recommended.

The data management aspect of the monitoring effort is the shared responsibility of the field surveyor, the park and network GIS specialists and data managers, and the network geomorphologic monitoring project manager. The field surveyor is responsible for field data collection and initial data download. The field surveyor should work closely with the network and/or park GIS specialist for additional post-processing, differential correction, data verification and data validation, preliminary data editing, and export to the designated GIS format. The network project manager is responsible for data documentation, data summary, and basic analysis and reporting.

The network is developing and packaging a suite of GIS tools to perform basic analysis of geomorphologic data. However, analysis with the GIS toolbox does not eliminate the need for professional analysis of data by a coastal scientist with knowledge of the relevant issues, resource, and processes. For a detailed discussion of data management procedures, refer to the data management sections of the protocol narrative and SOPs (under development). Ultimately, the NCBN geomorphologic monitoring project manager has the responsibility to see that adequate quality QA/QC procedures are built into the database management system and that appropriate data handling procedures are followed.

Qualifications and Training

An essential component in the collection of shoreline data is a knowledgeable, competent, and attentive field surveyor. Because visual interpretation of the shoreline is the essential element of the protocol, the ability of the field surveyor to consistently collect the target feature is critical to accurate data collection and comparability. The field surveyor should have a basic understanding of coastal and shoreline processes, familiarity with the resource and appearance of the shoreline expression on the local beach, competence and experience in the operation of the vehicle being used in the survey, and competence and experience in the operation of the GPS equipment being used in the survey. All of the NCBN ocean parks have either local park staff or ready access to cooperators with knowledge and expertise in all of these areas. The NCBN will assess the situation in each park and designate and train local staff as required. (See SOP #2 Personnel Requirements and Training).

Application of the data derived from implementation of the shoreline protocol at the local park level is a primary goal of the NCBN monitoring program. The Geomorphology Toolbox, a set of basic display and analysis GIS tools customized for coastal park use, will allow park managers and staff to access and use the monitoring data (Rodriguez 2004). In addition, the network has plans to develop and provide GIS and related training to selected park staff to ensure maximum integration of the data collected under this protocol. Initial efforts in developing the GIS training, including integration of the Geomorphology Toolbox into an ArcGIS training program will take place at NPS ASIS in the fall and winter of 2004 and 2005.

VIII. Operational Requirements

Annual Workload and Field Schedule

GPS surveys will be conducted in early spring (mid to late April) and early fall (early to mid October), a period that coincides with the peak expression of seasonal beach variability in the NCBN ocean parks. Extreme tide and weather events will preclude the scheduling of surveys to specific annual dates. Shoreline surveys require one person although the survey could benefit from the use of one or more additional staff if qualified persons and the necessary equipment are available. Approximately five field days (one full work week) should be allocated to complete each survey.

Facility and Equipment Needs

The equipment needed for the field survey consists of an all terrain vehicle (ATV – four wheel quad is recommended), appropriate safety gear such as helmet, goggles, and gloves, and a cartographic quality GPS unit capable of sub-meter accuracy, single point position collection, and post-processed differential correction (e.g. Trimble ProXR or equivalent). If two or more surveyors work simultaneously, field equipment requirements will increase accordingly. Should a park lack the proper equipment, the network will attempt to arrange for the availability of the necessary items to conduct the survey.

A computer and peripheral devices with appropriate ports and cables, GPS processing software (Trimble Pathfinder Office) for download, initial QA/QC, and export to ESRI GIS format are required to complete the initial tasks. The GIS component consists of the ESRI ArcGIS software along with the Spatial and 3D Analyst extensions, and the NPS NCBN Geomorphology Toolbox (Rodriguez 2004). The toolbox is a GIS utility that will assist users in the display, manipulation, and basic analysis of geomorphologic monitoring data such as shorelines, elevation profiles, and LIDAR survey data. Regardless of the number of field surveyors deployed, office computing needs remain as stated above. Specifics for equipment needs are detailed in SOP #1 – Equipment Needs.

Startup Costs and Budget

Startup costs consist of the ATV, the GPS unit, and if the survey is planned and executed locally, the surveyor's time (Table 2). If NCBN staff or their partners are required to perform the survey, staff time plus travel expenses covering a one-week per survey deployment will constitute the major costs. Equipment consists of a cartographic quality GPS unit, an ATV, and a computer running ESRI GIS software. All of these items are available at parks, or could be acquired by the network. Gasoline for survey vehicle, media for backup of data, and other such costs are considered minimal and incidental.

Item/Activity	1st Year Cost	5 YearTotalCost	Annual Cost	Annual Cost per Park	PerSurveyCost
ATVs (4)[1]	26000	26000	5200	1300	650
GPS (4)[2]	40000	40000	8000	2000	1000
Personnel[3]	12000	60000	12000	3000	1500
Total	78000	126000	25200	6300	3150

Table 2 – Data Collection Cost Estimates.
1= NCBN purchases 1 ATV for each ocean park; 2= NCBN purchases 1 GPS per ocean park; 3= Based on 8 weeks (2 weeks per park) at GS9;

Procedure for Revising the Protocol and Archiving Previous Versions of the Protocol

Over time, revisions to both the Protocol Narrative and to specific Standard Operating Procedures (SOPs) are to be expected. Complete documentation of changes to the protocol, and a library of previous protocol versions are essential for maintaining consistency in data collection, and for appropriate treatment of the data during data summary and analysis. The MS Access database for each monitoring component contains a field that identifies which version of the protocol was being used when the data were collected.

The rationale for including a narrative with supporting SOPs is based on the following:

- The Protocol Narrative is a general overview of the protocol that gives the history and justification for doing the work and an overview of the sampling methods, but that does not provide all of the procedural details. The Protocol Narrative will only be revised if major changes are made to the protocol.
- The SOPs, in contrast, are very specific step-by-step instructions for performing a given task. They are expected to be revised more frequently than the Protocol Narrative.
- When a SOP is revised, in most cases, it is not necessary to revise the Protocol Narrative to reflect the specific changes made to the SOP.
- All versions of the Protocol Narrative and SOPs will be archived in a Protocol Library.

The steps for changing the protocol (either the Protocol Narrative or the SOPs) are outlined in the "Revising the Protocol SOP". Each SOP contains a Revision History Log that should be filled out each time a SOP is revised to explain why the change was made, and to assign a new Version Number to the revised SOP. The new version of the SOP and/or Protocol Narrative should then be archived in the Long Term Ecological Monitoring Protocol Library.

IX. References

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